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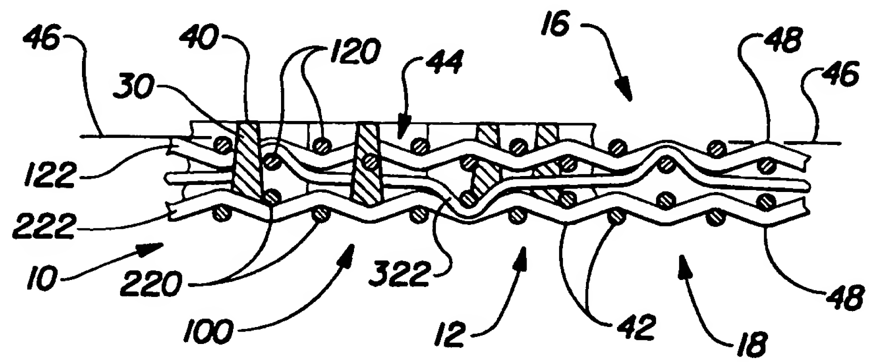
(54) Title: MULTIPLE LAYER FORAMINOUS BELTS WITH FUGITIVE TIE YARNS

(57) Abstract



A belt (10) for supporting a cellulosic fibrous structure in a papermaking process. The belt comprises a reinforcing structure (12) having two layers (16, 18), a web contacting first layer and a machine facing second layer and a pattern layer (30) comprised of a cured photosensitive resin, the pattern layer having a plurality of conduits (44) therethrough. The two layers are joined together by either integral or adjunct tie yarns (322) at least a portion of the tie yarns which lies within the conduits being removable after the photosensitive resin has been cured. A method for producing such belts is also disclosed.

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MULTIPLE LAYER FORAMINOUS BELTS WITH FUGITIVE TIE YARNS

FIELD OF THE INVENTION

The present invention relates to belts, and more particularly to foraminous belts comprising a resinous framework and a reinforcing structure that are useful in papermaking. Still more particularly the present invention relates to such belts having a reinforcing structure with at least two layers wherein the reinforcing structure has removable tie yarns which temporarily join the layers.

BACKGROUND OF THE INVENTION

Cellulosic fibrous structures, such as paper towels, facial tissues, and toilet tissues, are a staple of every day life. The large demand for and constant usage of such consumer products has created a demand for improved versions of these products and, likewise, improvement in the methods of their manufacture. Such cellulosic fibrous structures are manufactured by depositing an aqueous slurry from a headbox onto a Fourdrinier wire or a twin wire papermaking machine. Either such type forming wire is an endless belt through which initial dewatering occurs and fiber rearrangement takes place.

After the initial formation of the web, which becomes the cellulosic fibrous structure, the papermaking machine transports the web to the dry end of the papermaking machine. In the dry end of a conventional papermaking machine, a press felt compacts the web into a single region cellulosic fibrous structure prior to final drying. The final drying is usually accomplished by a heated drum, such as a Yankee drying drum.

One of the significant improvements to the manufacturing process, which yields a significant improvement in the resulting consumer products, is the use of through-air drying to replace conventional press felt dewatering. In through-air drying, like press felt drying, the web begins on a forming wire, which receives an aqueous slurry of less than one percent consistency from a headbox. Typically, initial dewatering takes place on the forming wire. The forming wire is not typically exposed to web consistencies of greater than about 30 percent. From the forming wire, the web is transferred to an air pervious through-air-drying fabric.

Air passes through the web and the through-air-drying fabric to continue the dewatering process. The air passes the through-air-drying fabric and the web while the

belt and the web are driven over vacuum transfer slots, other vacuum boxes or shoes, predryer rolls, etc. As a result, the web is molded to the topography of the through-air-drying fabric and the consistency of the web increases. Such molding creates a more three-dimensional web, but also can cause pinholes, if the fibers are deflected so far in the third dimension that a breach in fiber continuity occurs. As is known in the art, a pinhole is a small diameter hole in a paper web caused by incomplete formation of the web.

The web is then transported to the final drying stage where the web is also imprinted. At the final drying stage, the through-air-drying fabric transfers the web to a heated drum, such as a Yankee drying drum for final drying. During this transfer, portions of the web are densified during imprinting, to yield a multi-region structure. Many such multi-region structures have been widely accepted as preferred consumer products. An example of an early through-air-drying fabric which achieved great commercial success is described in commonly assigned U.S. Patent 3,301,746, issued Jan. 31, 1967 to Sanford et al.

Over time, further improvements became necessary. A significant improvement in through-air-drying fabrics is the use of a resinous framework on a reinforcing structure to provide through-air-drying belts. This arrangement allows drying belts to impart, continuous patterns, or, patterns in any desired form, rather than only the discrete patterns achievable by the woven belts of the prior art. Examples of such belts and the cellulosic fibrous structures made thereby can be found in commonly assigned U.S. Patents 4,514,345, issued Apr. 30, 1985 to Johnson et al.; 4,528,239, issued Jul. 9, 1985 to Trokhan; 4,529,480, issued Jul. 16, 1985 to Trokhan; and 4,637,859, issued Jan. 20, 1987 to Trokhan. The foregoing four patents are incorporated herein by reference for the purpose of showing preferred constructions of patterned resinous framework and reinforcing-element type through-air-drying belts, and the products made thereon. Such belts have been used to produce extremely commercially successful products such as BOUNTY paper towels and CHARMIN ULTRA toilet tissue, both produced and sold by the instant assignee.

As noted above, such through-air-drying belts used a reinforcing element to stabilize the resin. The reinforcing element also controlled the deflection of the papermaking fibers resulting; from vacuum applied to the backside of the belt and airflow through the belt. The early belts of this type used a fine mesh reinforcing element. While such a fine mesh was acceptable from the standpoint of controlling fiber

deflection into the belt, it was unable to withstand the environment of a typical papermaking machine for extended periods of running time. For example, such a belt was so flexible that destructive folds and creases often occurred. Also, the fine yarns did not provide adequate seam strength and would often burn at the high temperatures encountered in papermaking causing holes in the tissue web.

A new generation of patterned resinous framework and reinforcing structure through-air-drying belts addressed some of these issues. this generation utilized a dual layer reinforcing structure having vertically stacked machine direction yarns. A single cross-machine direction yarn system tied the two machine direction yarns together. Such dual layer designs allowed the use of coarser weave patterns and larger diameter yarns to address the seam strength and burn-through issues while, at the same time maintaining sufficient stiffness to resist folding and creasing on a papermaking machine.

As such resinous framework and reinforcing structure belts were used to make tissue, such as the commercially successful CHARMIN ULTRA noted above, new issues arose. For example, one problem in tissue making is the formation of small pinholes in the deflected areas of the web. Pinholes are strongly related to the depth that the web deflects into the belt. The depth comprises both the thickness of the resin on the reinforcing structure, and any pockets within the reinforcing structure that permits the fibers to deflect beyond the imaginary top surface plane of the reinforcing structure. Typical stacked machine direction yarn dual layer reinforcing structure designs have a variety of depths resulting from the particular weave configuration. The deeper the depth within a particular location of the weave that is registered with a deflection conduit in the resin, the greater the proclivity for a pinhole to occur in that area.

Recent work has shown that the use of triple layer reinforcing structures unexpectedly reduces occurrences of pinholes. Triple layer reinforcing structures comprise two completely independent woven layers, each having its own particular machine direction and cross-machine direction mesh. The two independent woven layers are typically linked together with tie yarns. More particularly, the triple layer belt preferably uses a finer mesh square weave as the upper layer, to contact the web and minimize pinholes. The lower layer or machine facing layer utilizes coarser yarns to increase rigidity and improve seam strength. The tie yarns may be machine direction or cross-machine direction yarns specifically added and which were not present in either layer (adjunct tie yarns). Alternatively, the tie yarns may be comprised of cross-machine direction or machine direction tie yarns from the upper and/or lower layer of the

reinforcing structure (integral tie yarns). *Machine direction yarns are preferred for the tie yarns because of the increased seam strength they provide.* While such triple layer belts have provided considerable improvement in pinhole reduction, further improvements are still desirable. For example, the presence of tie yarns in a conduit causes those conduits where a tie yarn is present to have a smaller projected open area than conduits where no tie yarns are present with resulting differences in permeability. As a result fibers may deflect differently into conduits having a tie yarn present than such fibers would deflect into the remaining conduits without such tie yarns.

The papermaking art has considered increasing the permeability of fabrics used on papermaking machines. For example, needled drying felts originally used a relatively open woven base cloth onto which staple fibers could be needled to form the felt. In an attempt to improve the permeability of such felts, the art developed a support structure comprising a sheet of uniformly spaced, parallel warp threads as a replacement for the woven base cloth (weftless felts). However, such weftless felts had deficient structural stability during the needling process and when running on a papermaking machine. Such lack of structural stability is known to the art as "sleaziness". One approach to improved structural stability is described in British Patent Specification 1,230,654, published on May 5, 1971 in the name Scapa-Porritt Limited. Disclosed therein is a method of producing a needled paper machine felt where the woven base cloth has machine-direction yarns as are typically employed and cross-machine direction yarns at least some of which are insoluble in aqueous media and at least some of which are said to be soluble in aqueous media. Dissolving out the soluble yarns (or parts thereof) of the base cloth is also disclosed. While improvements in sleaziness may be obtained from the use of soluble yarns in papermaking felts, such improvements fail to address the differences in fiber deflection resulting from the use of tie yarns that is discussed above. Further, the '654 patent specification fails to address the need to maintain the filaments (layers) of a multiple layer fabric in a preferred relationship as is provided by the tie yarns of the triple layer fabrics discussed above.

Another area of needed improvement is additional pinhole reduction or elimination. When a belt comprising a reinforcing structure with top layer integral tie yarns, the loss of support whenever the tie yarn dives to the lower layer to join the two layers can cause pinholes. That is, when integral tie yarns are used, different conduits have differing potential for pinholing with resulting increased difficulty in control of the papermaking process.

Accordingly, it is an object of this invention to provide a belt which has improved uniformity in open area and reduced pinholing potential among the deflection conduits thereof. It is a further object of the present invention to provide such improved uniformity without a reduction in the suitability of such belts for the papermaking process or a reduction in the suitability of the reinforcing structures therein for the belt making process. It is still a further object of the present invention to provide reinforcing structures having tie yarns which provide stability between the layers of a multi-layer reinforcing structure during the belt making process while, at the same time, providing belts that have satisfactory durability for the papermaking process. It is yet a further object of the present invention to provide such belts wherein any tie filaments that may be present therein do not interfere with the open area of the conduits thereof.

SUMMARY OF THE INVENTION

The present invention comprises a support belt for a cellulosic fibrous structure. The belt comprises a reinforcing structure and a pattern layer.

The reinforcing structure comprises two layers a web facing layer and a machine facing layer. The web facing layer is woven from yarns that are substantially transparent to actinic radiation. Preferably, at least a portion of the yarns comprising the machine facing layer are substantially opaque to actinic radiation.

The two layers are joined by fugitive tie yarns which stabilize the relationship between the layers while the belt is being produced. The tie yarns may be adjunct cross-machine direction or adjunct machine direction tie yarns interwoven with respective machine direction yarns or cross-machine direction yarns of the first and second layers. The tie yarns may also be integral tie yarns which tie the first layer and second layer relative to one another and which are woven within the respective planes of the first and second layers and additionally are interwoven with the respective yarns of the other layer.

The pattern layer extends from the backside of the machine facing layer through and beyond the web facing layer to form at least a portion of the web contacting surface of the belt. The pattern layer comprises a cured photosensitive resin. The pattern layer is further provided with a plurality of conduits that extend through the cured resin so the web contacting surface and the backside of the belt are in fluid contact.

The web facing layer and the machine facing layer of the reinforcing structure are also temporarily joined by fugitive adjunct tie yarns that are interwoven with each layer. The tie yarns are substantially transparent to actinic radiation and can be removed by chemical or mechanical processes when they are no longer needed to stabilize the relationship between the web facing layer and the machine facing layer of the reinforcing structure. In particular, that portion of the fugitive adjunct tie yarns that lies within the conduits can be removed so that belt properties, such as projected open area, are substantially isotropic across the belt. A preferred means to remove the fugitive adjunct tie yarns is the combination of solubilization and mechanical energy provided by the showering systems that are part of the beltmaking and papermaking processes. Suitable materials are those that can be controllably removed by chemical or mechanical means.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a fragmentary top plan view of a belt of the present invention having the first and second layers tied together by fugitive adjunct tie yarns from the second layer, and shown partially in cutaway for clarity.

Figure 2 is a vertical sectional view taken along line 2–2 of Figure 1.

Figure 3 is a fragmentary top plan view of a belt according to the prior art, having permanent adjunct tie yarns and shown partially in cutaway for clarity.

Figure 4 is a vertical sectional view taken along line 4–4 of Figure 3 and having the pattern layers partially removed for clarity.

Figure 5A is a plan view identifying key elements of Figure 5B.

Figure 5B is a photomicrograph of a belt according to the present invention showing a fugitive adjunct tie yarn.

Figure 6A is a plan view identifying key elements of Figure 6B.

Figure 6B is a photomicrograph of a belt according to the present invention after the fugitive adjunct tie yarn of Figures 5A and 5B have been removed by washing.

DETAILED DESCRIPTION OF THE INVENTION

Referring to Figures 1 and 2, which show a belt 10 of the present invention The belt 10 of present invention is preferably an endless belt intended to convey cellulosic fibers

and like materials from one part of a papermaking process to another. For example, belt 10 is suitable for receiving such fibers in a fiber deposition step (i. e. serving as a forming wire) or for carrying such fibers from a forming wire to a drying step. Belt 10 comprises two primary elements: a reinforcing structure 12 and a pattern layer 30. The reinforcing structure 12 is further comprised of at least two layers, a web facing first layer 16 and a machine facing second layer 18. Each layer 16, 18 of the reinforcing structure 12 is further comprised of interwoven machine direction yarns 120, 220 and cross-machine direction yarns 122, 222. The preferred reinforcing structure 12 further comprises fugitive adjunct tie yarns 322 interwoven with the respective yarns 100 of the web facing layer 16 and the machine facing layer 18. As used herein, the term "yarns 100" is generic to and inclusive of machine direction yarns 120, cross-machine direction yarns 122 of the first layer 16, as well as machine direction yarns 220 and cross-machine direction yarns 222 of the second layer 18.

The second primary element of the belt 10 is the pattern layer 30. The pattern layer 30 is cast from a resin onto the top of the first layer 16 of the reinforcing structure 12. The pattern layer 30 penetrates the reinforcing structure 12 and is cured into any desired pattern by irradiating liquid resin with actinic radiation through a mask having a pattern of opaque sections and transparent sections.

Referring to Figure 2, the belt 10 has two opposed surfaces, a web contacting surface 40 disposed on the outwardly facing surface of the pattern layer 30 and an opposed backside 42. The backside 42 of the belt 10 contacts the machinery used during the papermaking operation. Such machinery (not illustrated) includes a vacuum pickup shoe, vacuum box, various rollers, etc.

The belt 10 may further comprise conduits 44 extending from and in fluid communication with the web contacting surface 40 of the belt 10 to the backside 42 of the belt 10. The conduits 44 allow deflection of the cellulosic fibers normal to the plane of the belt 10 during the papermaking operation.

The conduits 44 may be discrete, as shown, if an essentially continuous pattern layer 30 is selected. Alternatively, the pattern layer 30 can be discrete and the conduits 44 may be essentially continuous or both the pattern layer 30 and the conduits 44 may be semi-continuous. For example, a discrete pattern layer 30 and continuous conduits 44 is easily envisioned by one skilled in the art as generally opposite that illustrated in Figure 1. Such an arrangement, having a discrete pattern layer 30 and an essentially continuous conduit 44, is illustrated in Figure 4 of the aforementioned U.S. Patent 4,514,345 issued

to Johnson et al. and incorporated herein by reference. A semi-continuous conduit is described in commonly assigned U.S. Patent 5,628,876, issued to Ayers, et al. on May 13, 1997, the disclosure of which is incorporated herein by reference. Of course, it will be recognized by one skilled in the art that any combination of discrete, continuous, and semi-continuous patterns may be selected as well.

The pattern layer 30 is cast from photosensitive resin, as described above and in the aforementioned patents incorporated herein by reference. The preferred method for applying the photosensitive resin forming the pattern layer 30 to the reinforcing structure 12 in the desired pattern is to coat the reinforcing layer with the photosensitive resin in a liquid form. Actinic radiation, having an activating wavelength matched to the cure of the resin, illuminates the liquid photosensitive resin through a mask having transparent and opaque regions. The actinic radiation passes through the transparent regions and cures the resin therebelow into the desired pattern. The liquid resin shielded by the opaque regions of the mask is not cured and is washed away, leaving the conduits 44 in the pattern layer 30.

As described in U.S. Patent 5,566,724, issued to Trokhan, et al. on October 22, 1996 (the disclosure of which is incorporated herein by reference) providing UV opaque machine or cross-machine direction yarns to the second layer of a reinforcing structure and providing tie yarns that are substantially transparent to actinic radiation results in belts with desirable backside texture without the undesirable loss of resin lock-on whenever such tie yarns are disposed on the topside of the reinforcing structure. Similarly, with respect to the present invention, actinic radiation does not pass through the yarns 220, 222 of the second layer 18 which are substantially opaque. This results in a backside texture on the machine facing surface of the second layer 18. The backside texture is registered with the yarns 220, 222 of the second layer 18 having the second opacity and which are substantially opaque to actinic radiation. Air flow through the cellulosic fibrous structure and through the backside texture removes water from the cellulosic fibrous structure.

The pattern layer 30 extends from the backside 42 of the second layer 18 of the reinforcing structure 12, outwardly from and beyond the first layer 16 of the reinforcing structure 12. Of course, as discussed more fully below, not all of the pattern layer 30 extends to the outermost plane of the backside 42 of the belt 10. Instead, some portions of the pattern layer 30 do not extend below particular yarns 220, 222 of the second layer 18 of the reinforcing structure 12 so as to provide texture for facilitating air flow as

discussed above. The pattern layer 30 also extends beyond and outwardly from the web facing surface of the first layer 16 to, at least partially, define the depth of the deflection conduits 44. Preferably the pattern layer 30 extends a distance of about 0.002 inches (0.05 millimeter) to about 0.050 inches (1.3 millimeters) outwardly from the web facing surface of the first layer 16. The dimension of the pattern layer 30 perpendicular to and beyond the first layer 16 generally increases as the pattern becomes coarser. The distance the pattern layer 30 extends from the web facing surface of the first layer 16 is measured from the plane 46 in the first layer 16, furthest from the backside 42 of the second layer 18. As used herein, a "knuckle" is the intersection of a machine direction yarn 120, 220 and a cross-machine direction yarn 122, 222.

The term "machine direction" refers to that direction which is parallel to the principal flow of the paper web through the papermaking apparatus. The "cross-machine direction" is perpendicular to the machine direction and lies within the plane of the belt 10.

As noted above, different yarns 100 of the belt 10 may have a different opacity. The opacity of a yarn 100 is the ratio of the amount of actinic radiation which does not pass through the yarn 100 (due to either reflectance, scattering or absorption) to the amount actinic radiation incident upon the yarn 100. As used herein, the "specific opacity" of a yarn 100 refers to the opacity per unit diameter of a round yarn 100. It is to be recognized that the local opacity may vary throughout a given cross section of the yarn 100. However, that opacity refers to the aggregate opacity of a particular cross section, as described above, and not to the opacity represented by any of the different elements comprising the diameter.

The machine direction and cross-machine direction yarns 120, 122 are interwoven into a web facing first layer 16. Such a first layer 16 may have a one-over, one-under square weave, or any other weave which has a minimal deviation from the top plane 46. Preferably the machine direction and cross-machine direction yarns 120, 122 comprising the first layer 16 have a first opacity. The first opacity should be low enough so that the machine direction and cross-machine direction yarns 120, 122 comprising the first layer 16 are substantially transparent to actinic radiation which is used to cure the pattern layer 30. Such yarns 120, 122 are considered to be substantially transparent if actinic radiation can pass through the greatest cross-sectional dimension of the yarns 120, 122 in a direction generally perpendicular to the plane of the belt 10 and still sufficiently cure the photosensitive resin therebelow.

The machine direction yarns 220 and cross-machine direction yarns 222 are also interwoven into a machine facing second layer 18. The yarns 220, 222, particularly the cross-machine direction yarns 222, of the machine facing second layer 18 are preferably larger than the yarns 120, 122 of the first layer 16, to improve seam strength. This result may he accomplished by providing cross-machine direction yarns 222 of the second layer 18 which are larger in diameter than the machine direction yarns 120 of the first layer—if yarns 100 having a round cross section are utilized. If yarns 100 having a different cross section are utilized, this may be accomplished by providing machine direction yarns 220 in the second layer having a greater incident light path length than the machine direction yarns 120 of the first layer. Alternatively, and less preferably, the machine direction yarns 220 of the second layer 18 may be made of a material having a greater tensile strength than the yarns 120, 122 of the first layer 16.

In any embodiment, the machine direction and/or cross-machine direction yarns 220, 222 of the second layer 18 have a second opacity and/or second specific opacity, which is greater than the first opacity and/or first specific opacity, respectively, of the yarns 120, 122 of the first layer 16. The yarns 220, 222 of the second layer are preferably substantially opaque to actinic radiation. By "substantially opaque" it is meant that liquid resin in the shadow of yarns 220, 222 having such opacity does not cure to a functional pattern layer 30, but instead is washed away as part of the belt 10 manufacturing process.

The machine direction and cross-machine direction yarns 220, 222 comprising the second layer 18 may be woven in any suitable pattern, such as a square weave, as shown, or a twill or broken twill weave and/or any suitable shed. Preferably, the second layer 18 has a square weave, in order to maximize seam strength. If desired, the second layer 18 may have a cross-machine direction yarn 222 in every other position, corresponding to the cross-machine direction yarns 122 of the first layer. Generally, the machine direction yarns 220 of the second layer 18 occur with a frequency coincident that of the machine direction yarns 120 of the first layer 16, in order to preserve seam strength.

Fugitive tie yarns 322 join the first layer 16 and the second layer 18. The fugitive tie yarns 322 may be adjunct cross-machine direction or adjunct machine direction tie yarns interwoven with respective machine direction yarns or cross-machine direction yarns of the first and second layers. That is, adjunct tie yarns are independent of any weave selected for either of the first or second layers 16, 18, but, instead, such tie yarns are in addition to and may even disrupt the ordinary weave of such layers 16, 18. The tie yarns may also be integral tie yarns which tie the first layer and second layer relative to

one another and which are woven within the respective planes (i. e. part of the weave) of the first and second layers 16, 18 and, additionally, are interwoven with the respective yarns of the other layer. Adjunct and integral tie yarns are discussed in greater detail in the aforementioned U.S. Patent 5,566,724. While either integral or adjunct fugitive tie yarns are suitable for joining the first and second layers 16, 18 of the present invention, the first and second layers 16 and 18 are preferably joined by cross-machine direction fugitive adjunct tie yarns 322.

The preferred fugitive adjunct tie yarns 322 are interwoven between the first layer 16 and the second layer 18 to join the layers. As shown in Figures 1 and 2, the preferred fugitive adjunct tie yarns 322 are cross-machine direction tie yarns 322, which are interwoven with the respective machine direction yarns 120, 220 of the first and second layers 16, 18. Alternatively, the tie yarns may be machine direction tie yarns (not shown) which are interwoven with respective cross-machine direction yarns 122, 222 of the first and second layers 16, 18. Preferably, such tie yarns are smaller in diameter than the yarns 100 of the first and second layers 16, 18, so such tie yarns do not unduly reduce the projected open area of the belt 10. Also, as used herein, a tie yarn can be considered "fugitive" if at least a portion of the tie yarn can be at least partially removed by means that are encountered in the beltmaking process, the papermaking process, on in a process specifically designed to remove such yarns.

A preferred weave pattern for the fugitive adjunct tie yarns 322 has the least number of tie points necessary to stabilize the first layer 16 relative to the second layer 18. The tie yarns 322 are preferably oriented in the cross-machine direction because this arrangement is generally easier to weave. A suitable weave pattern is shown in Figure 1.

Contrary to the types of weave patterns dictated by the prior art, the stabilizing effect of the pattern layer 30 minimizes the number of tie yarns 322 necessary to engage the first layer 16 and the second layer 18. This is because the pattern layer 30 stabilizes the first layer 16 relative to the second layer 18 once casting is complete and during the paper manufacturing process. Accordingly, smaller and fewer fugitive adjunct tie yarns 322 may be selected, than the yarns 100 used to make the first or second layers 16, 18.

Referring to Figures 3 and 4, which show a prior art belt 110 of the aforementioned U.S. Patent 5,566,724, the permanent adjunct tie yarns 422 thereof intrinsically obstruct certain of the conduits 44. That is, whenever a tie yarn 422 happens to lie in a conduit 44, an additional portion of the projected open area of the conduit 44 is obstructed by the tie yarn 422. This obstruction of the conduits 44 can cause a difference in effective fiber

support which may result in differences in finished product uniformity. Further, if limiting orifice drying, such as is beneficially described in commonly assigned U.S. Patent 5,274,930 issued Jan. 4, 1994 to Ensign et al. is desired, it becomes even more important that the belt 10 has sufficient open area.

The prior art addresses this problem by providing permanent adjunct tie yarns 422 comprising relatively fewer and smaller yarns, because the permanent adjunct tie yarns 422, of course, block the projected open area through the belt 10. Such structure minimizes the effect of the tie yarns 422 on product uniformity. However, it is desirable to even further minimize such effect. As is discussed below, the present invention further improves product uniformity by providing fugitive adjunct tie yarns 322 wherein the tie yarn is removed in either the belt making process (after the pattern layer 30 stabilizes the first layer 16 relative to the second layer 18), in a process designed to remove such tie yarns, or on a papermaking machine. The Applicants have found that, depending on the relationship between the diameters of the yarns 100, the pattern layer 30 and the diameter of the fugitive adjunct tie yarns 322, the present invention (i.e. removing a tie yarn from a conduit 44 where one is present) results in an increase in projected open area of between about 5% and about 20% for that conduit when compared to belts of the prior art. For a belt 10 woven using materials typical of those practiced in the prior art, the increase in projected open area is about 14%. The projected open area of a belt 10 may be determined (providing it is not too transparent) in accordance with the method for determining projected average pore size set forth in commonly assigned U.S. Patent 5,277,761 issued Jan. 11, 1994 to Phan and Trokhan, which patent is incorporated herein by reference for the purpose of showing a method to determine the projected open area of the reinforcing structure.

Preferably, such belts have an air permeability of at least about 600 standard cubic feet per minute per square foot (183 cubic meters per minute per square meter). More preferably, the air permeability is at least about 900 standard cubic feet per minute per square foot (274 cubic meters per minute per square meter). he term "air permeability" as used herein is measured as the number of cubic feet (cubic meters) of air per minute that pass through a one square foot (one square meter) area of the belt 10 at a pressure drop across the thickness of the belt 10 equal to about 0.5 inch (1.2 centimeter) of water. The air permeability is measured using a Valmet permeability measuring device (Model Wigo Taifun Type 1000) available from the Valmet Corp. of Helsinki, Finland.

In weaving a reinforcing structure 12 of the present invention, the fugitive adjunct tie yarns 322 are treated in essentially the same manner as permanent adjunct tie yarns 422 of the prior art. That is, prior art weave patterns that use tie yarns 422 or the like are also suitable for stabilizing the reinforcing structure 12 of the present invention.

In addition, fugitive adjunct tie yarns provide additional weave pattern flexibility (not shown). Examples of such flexibility include:

- Because such tie yarns can be readily removed by simple process steps, weave patterns having more tie yarns than would be typically used by the prior art could be used. Such additional tie yarns could be used for applications where maintenance of registration between layers of a reinforcing structure is particularly important or where the photosensitive resin is particularly valuable and the removable volume of a fugitive tie yarn prevents such valuable resin from filling volume that would be part of a conduit in the finished belt.

- Fugitive yarns could also be used to replace certain of the machine direction or cross direction yarns that form a portion of the backside surface 42 of a belt (e.g. certain of yarns 220 or 222). Since such yarns can be removed by additional process steps, their removal is an alternate means to provide texture for facilitating air flow as is discussed above. Obviously, the designer would need to be careful that any weave pattern chosen would not replace so many of the yarns 220, 222 that the resulting substrate would be inadequate in any required property, such as seam strength.

These are but a few of the possible examples of the additional flexibility fugitive yarns provide to a designer of weave patterns for belt reinforcing structures.

In order that the fugitive adjunct tie yarns 322 are removed in either the belt making process (after the pattern layer 30 stabilizes the first layer 16 relative to the second layer 18) or on a papermaking machine, the fugitive adjunct tie yarns 322 must comprise a material that can be removed from the conduits 44 by biological means, chemical means, mechanical means, or any combination of biological, chemical and mechanical means. That is, the fugitive adjunct tie yarns 322 may be removed by dissolution, hydrolysis (chemical or enzymatically catalyzed), photodegradation, oxidation, or by providing predetermined sites of mechanical failure. For example, a monofilament yarn extruded from the polyacrylate resin described in U.S. Patent 4,870,148, issued to Belz, et al. on September 26, 1989 would be soluble in an alkaline

medium. Preferably, the fugitive adjunct tie yarns 322 comprise a material which is removable by the combination of mechanical energy and solubilization that is provided by the showers that are part of the beltmaking and papermaking processes. In keeping with the need to stabilize the reinforcing structure 12 during the beltmaking process, it is preferred that the fugitive adjunct tie yarns 322 comprise a material that is not removed until after the resin comprising the pattern layer 30 penetrates the reinforcing structure 12 and is cured.

More preferably, the fugitive adjunct tie yarns 322 comprise a polymeric material that has partial water solubility. In this manner, the tie yarns 322 will maintain at least partial mechanical integrity until after the resin comprising the pattern layer 30 is cured. For example, the fugitive adjunct tie yarns 322 can comprise polymeric materials such as poly (ethylene oxide) or polyvinyl alcohol. Polyvinyl alcohol is particularly preferred because, controlling the degree of hydrolysis of the precursor polyvinyl acetate, controls the water solubility of the resulting polyvinyl alcohol. Such yarns can be either monofilament yarns or multifilament yarns. Suitable polyvinyl alcohol yarns having a fiber dissolution temperature of about 80°C are available from Kuraray Co., Ltd. of Osaka, Japan as Kuralon K-II.

As discussed above, fugitive adjunct tie yarns 322 comprising such limited solubility resins are resistant to the initial showering that is part of the beltmaking process. As a result, reinforcing structures 12 of the present invention maintain a form similar to that shown in Figure 4 throughout the beltmaking process, providing needed stability to the reinforcing structure 12. Once the pattern layer 30 is cured so it is capable of stabilizing the layers 16, 18, the solubilization and mechanical energy of further showering removes that portion of the fugitive tie yarns that lie in the conduits 44 so that the projected open area is maximized. Such showering can take place either on a beltmaking apparatus or on a papermaking machine. Once the portion of the fugitive adjunct tie yarns 322 that lies in the conduits is removed, the belt 10 takes the form shown in Figures 1 and 2 where the conduits 44 are substantially isotropic.

In keeping with the desired maximization of resin lockon, the fugitive adjunct tie yarns 322 also have an opacity and/or specific opacity which is less than the second opacity and/or second specific opacity, respectively, of the machine direction yarns 220 of the second layer 18. Preferably, the fugitive adjunct tie yarns 322 are substantially transparent to actinic radiation.

In an alternative embodiment of the present invention (not shown), the fugitive adjunct tie yarns 322 can be provided with predetermined sites of mechanical failure whereby the tie yarns 322 are weakened such that they can be removed by mechanical energy (e. g. as provided by showering). For example, a monofilament material that is suitable for use as a tie yarn 422 of the prior art could be provided with a pattern of notches having a repeat length on the order of or less than the repeat length of the pattern of conduits 44 so it becomes suitable as a fugitive adjunct tie yarn 322. As a result, the probability of at least such notch lying in most of the conduits having a tie yarn is high. Since the notches weaken the tie yarn, the combination of machine stretch and showering energy will cause such weakened tie yarns to break within the conduit 44. One of skill in the art will recognize that, because not all such tie yarns will break, the properties of belts 10 having notched, fugitive adjunct tie yarns 322 will be intermediate those of belts of the prior art and belts having soluble, fugitive tie yarns 322 as described above. Fugitive adjunct tie yarns 322 according to the present invention wherein the tie yarns comprise materials that become chemically weakened (e. g. by accelerated hydrolysis or by photodegradation that is initiated by the UV light of the casting process) are also envisioned.

A suitable method of casting a belt 10 having a reinforcing structure 12 comprising fugitive tie yarns 322 and removing the yarns after they are no longer needed is as follows. A reinforcing structure 12 can be woven such that it comprises fugitive tie yarns 322 having a solubilization temperature tailored to the desired shower water temperature (as is discussed below) according to the present invention. Using the methods described above and more completely in the above mentioned U.S. Patent 4,514,345, cast and cure a liquid, photosensitive resin on the reinforcing structure 12 to provide a pattern layer 30 which stabilizes the relationship between the first and second layers 16, 18. Such casting methods include showering to remove the uncured resin to form the conduits 44 (Preferably, the shower water temperature for such a showering step is between about 50°C and about 90°C). Shower the belt 10 a second time using shower water wherein the temperature has been increased about 10°C such that it above the solubilization temperature of the resin used to extrude the fugitive tie yarn 322 to remove that portion of the fugitive tie yarn 322 lying in the conduits 44.

One of skill in the art will recognize that alternative process steps to remove the fugitive tie yarns 322 are also suitable. For example, the fugitive tie yarns 322 could be cooled to less than its brittle/ductile transition temperature (the remaining yarns 100, 200 and the cured photosensitive resin remaining above their respective brittle/ductile

transition temperatures) and mechanical energy applied to cause the tie yarns 322 to shatter so they open up the conduits 44. The fugitive tie yarns 322 could comprise a material having a melting point substantially lower than the remaining yarns 100 used to weave the reinforcing structure 12. Subjecting the reinforcing structure 12 to a temperature higher than the melting point of the fugitive tie yarns 322 would cause the tie yarns 322 to liquefy. Capillary forces would then cause the liquefied tie yarn material to flow to intersections between the remaining yarns 100. Upon cooling, the melted tie yarns 322 would serve to maintain the relative relationship between the layers 16, 18 without interfering with the open area of the conduits 44. These and other similar methods of maintaining the relative relationship between the first layer 16 and the second layer 18 until such relationship is stabilized by the pattern layer 30 are contemplated as alternative embodiments of the present invention.

The following example is presented for illustrative purposes and not by way of limitation.

EXAMPLE

A reinforcing structure 12 according to the art as shown in Figures 3 and 4 can be woven according to methods known to those of skill in the art. Such a structure 12 comprises 11 machine direction yarns 120 per centimeter in the first layer 16 and 11 machine direction yarns 220 per centimeter in the second layer 18. Both yarns 120 and 220 comprise polyester monofilament 0.24 millimeters in diameter as is available from Shakespeare, Monofilament Division of Columbia, SC. The reinforcing structure 12 also comprises 11 cross-machine direction yarns 122 per centimeter in the first layer 16 and 6 cross-machine direction yarns 222 per centimeter in the second layer 18. Monofilament yarns having a 0.25 millimeter diameter and 0.3 millimeter were used as yarns 122 and 222 respectively. Such yarns are also available from Shakespeare. The reinforcing structure 12 still further comprises 6 cross-machine direction tie yarns 422 per centimeter. A suitable non fugitive tie yarn 422 has a diameter of 0.15 millimeter and is available from Shakespeare. Such woven reinforcing structures 12 are available from Albany International, Appleton Wire Division of Appleton, WI. For purposes of the present example and to simulate a reinforcing structure 12 of the present invention, one of these tie yarns is replaced by two strands of a water soluble (80°C), polyvinyl alcohol yarn (available from Kuraray Co., Ltd. of Osaka Japan) to provide a fugitive tie yarn 322 (see Figures 5A and 5B).

A pattern layer 30 is cast on the above described reinforcing structure 12 by exposing a photosensitive resin to light through a mask according to the methods described in the above mentioned U.S. Patent 5,566,724. Washing with water having a temperature of about 75°C removes uncured resin from the nascent belt 10. Figures 5A and 5B depict a portion of the belt after the uncured resin has been removed with the fugitive tie yarn 322 visible in the center of the conduit 44. As is clearly depicted in Figures 6A and 6B, raising the water temperature by about 10°C and washing a second time substantially dissolves that portion of the fugitive tie yarn 322 that lies in the conduit 44.

The disclosures of all patents, patent applications (and any patents which issue thereon, as well as any corresponding published foreign patent applications), and publications mentioned throughout this description are hereby incorporated by reference herein. It is expressly not admitted, however, that any of the documents incorporated by reference herein teach or disclose the present invention.

While particular embodiments of the present invention have been illustrated and described, it would be obvious to those skilled in the art that various other changes and modifications can be made without departing from the spirit and scope of the invention. It is therefore intended to cover in the appended claims all such changes and modifications that are within the scope of this invention.

What is claimed is:

1. A reinforcing structure suitable for use in papermaking, said reinforcing structure comprising:

   a plurality of layers of woven yarns, wherein each of said layers comprises a separate weave pattern wherein a portion of said yarns in each of said layers are directed in a machine direction and a portion of said yarns in each of said layers are directed in a cross direction; and

   a multiplicity of tie yarns joining said layers to form said reinforcing structure, characterized in that at least a portion of said tie yarns are fugitive tie yarns.

2. A reinforcing structure to Claims 1 or 2 wherein said plurality of layers comprises a first layer and a second layer and said first layer and said second layer are joined by interweaving said tie yarns into said weaves of said first and second layers in said machine direction.

3. A reinforcing structure to Claims 1 or 2 wherein said plurality of layers comprises a first layer and a second layer and said first layer and said second layer are joined by interweaving said tie yarns into said weaves of said first and second layers in said cross direction.

4. A reinforcing structure according to any of the above claims wherein said tie yarns are integral tie yarns.

5. A reinforcing structure according to Claims 1, 2, or 3 wherein said tie yarns are adjunct tie yarns.

6. A reinforcing structure according to any of the above claims wherein said fugitive tie yarns comprise a water soluble polymer.

7. A support belt for a cellulosic fibrous structure, said support belt having a web contacting surface, a backside and comprising:

   a reinforcing structure according to any of the above claims; and

   a pattern layer which extends from said backside through and beyond said first layer to form at least a portion of said web contacting surface of said belt, said pattern layer comprising a cured photosensitive resin and being provided with a

plurality of conduits therethrough, said conduits providing a means of fluid communication between said web contacting surface and said backside, wherein at least a portion of said tie yarns that lie in said conduits is removable without causing substantial damage to the remaining portion of said reinforcing structure or said pattern layer.

8. A belt according to Claim 8 wherein said tie yarns are removed by chemical means.

9. A belt according to Claim 8 wherein said tie yarns are removed by dissolution.

10. A belt according to Claim 8 wherein said tie yarns are removed by mechanical means, said mechanical means preferably comprising a showering system.

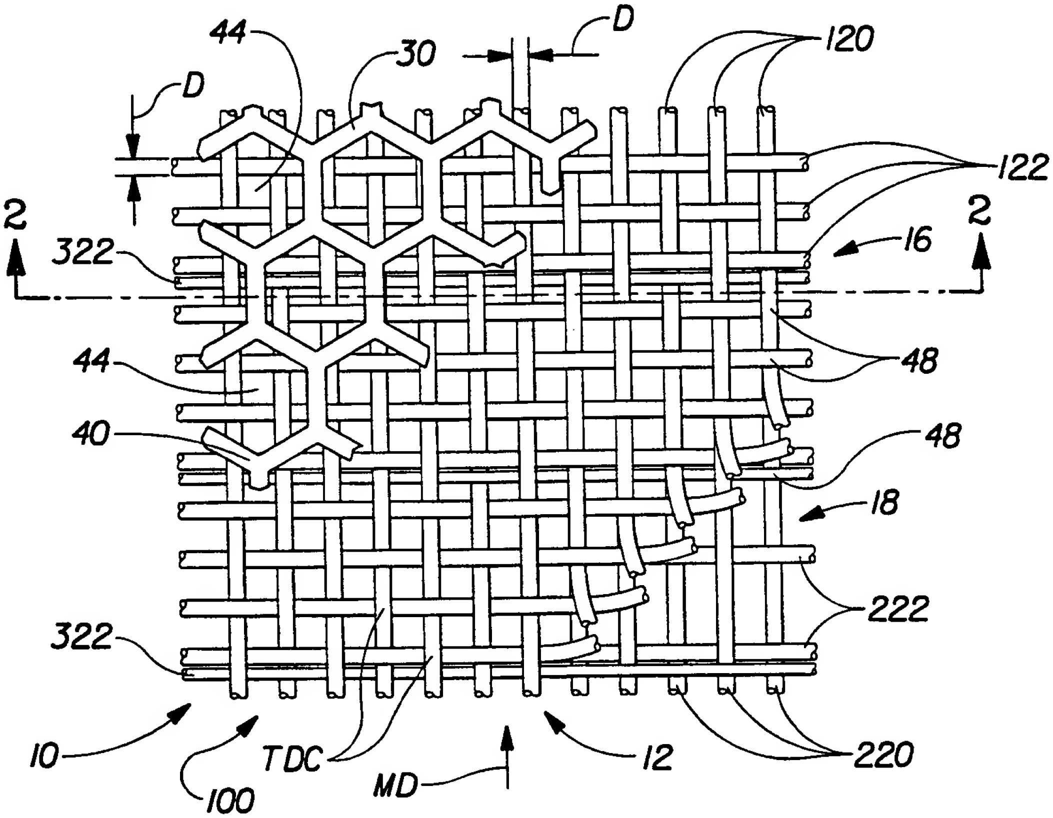
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Fig. 1

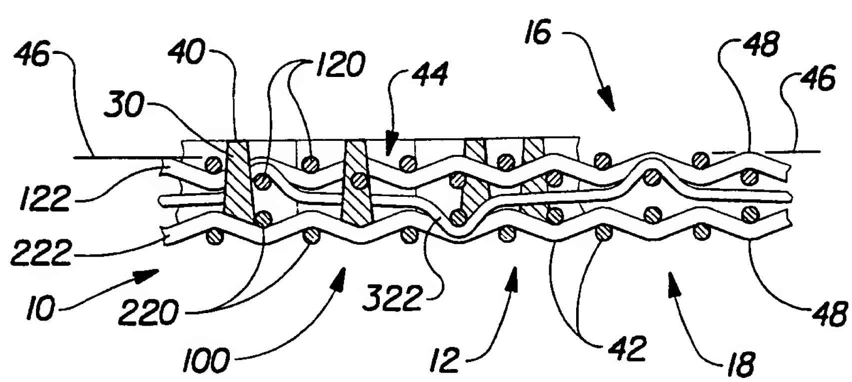
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Fig. 2

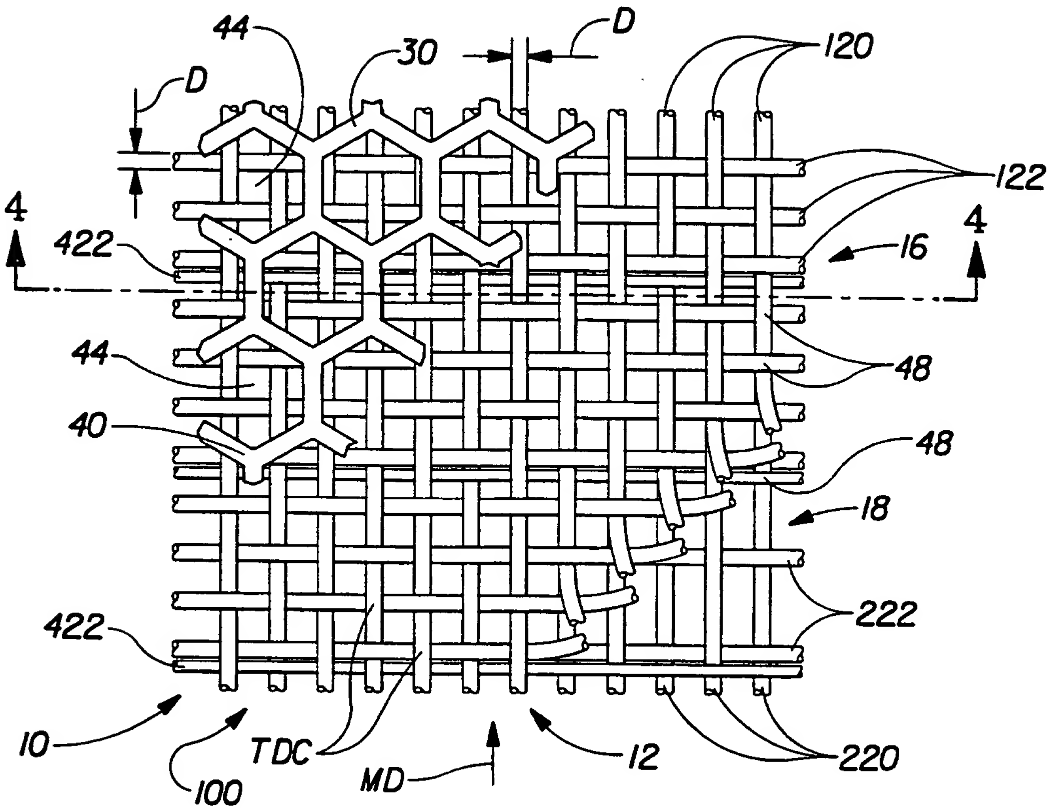

Fig. 3
Prior Art

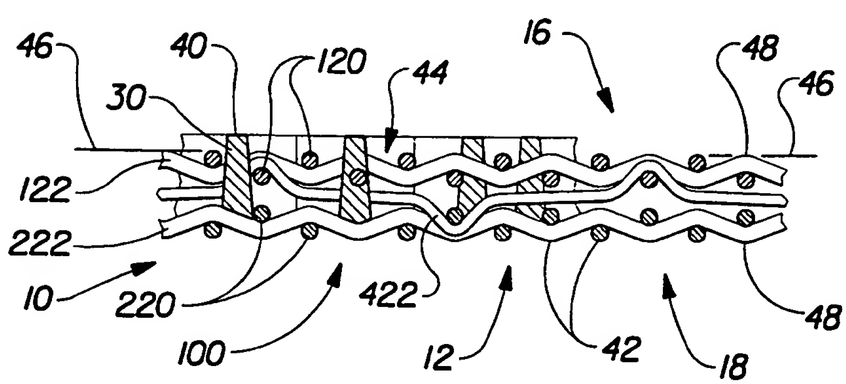

Fig. 4
Prior Art

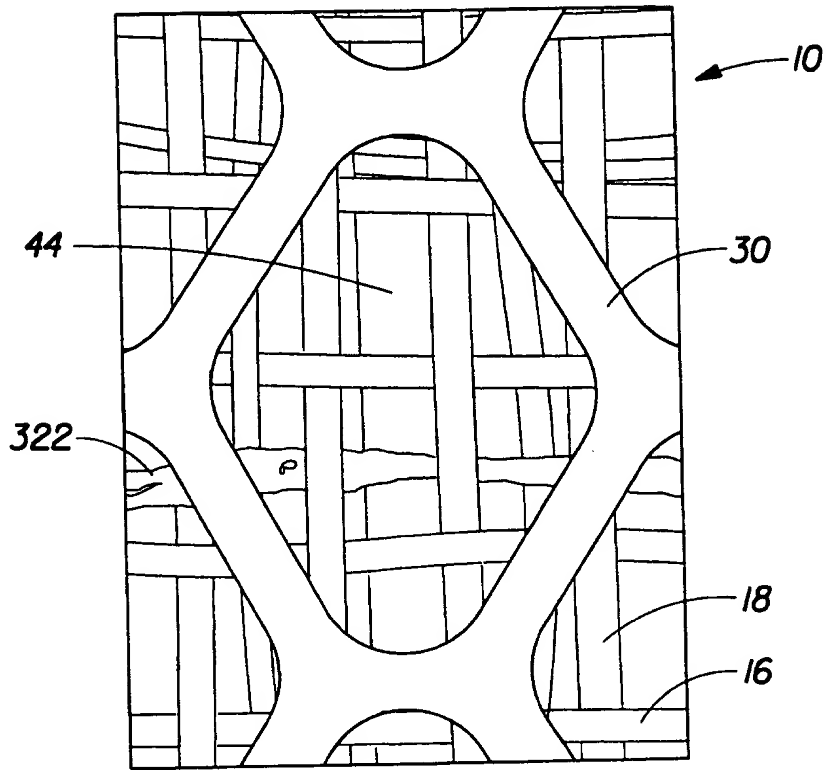

Fig. 5A

Fig. 5B

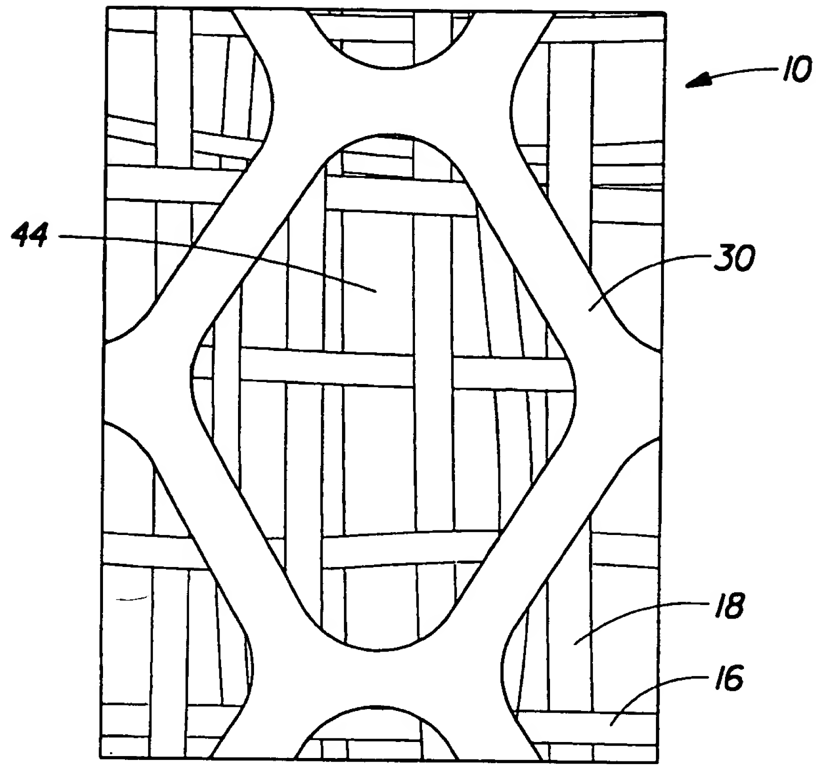

Fig. 6A

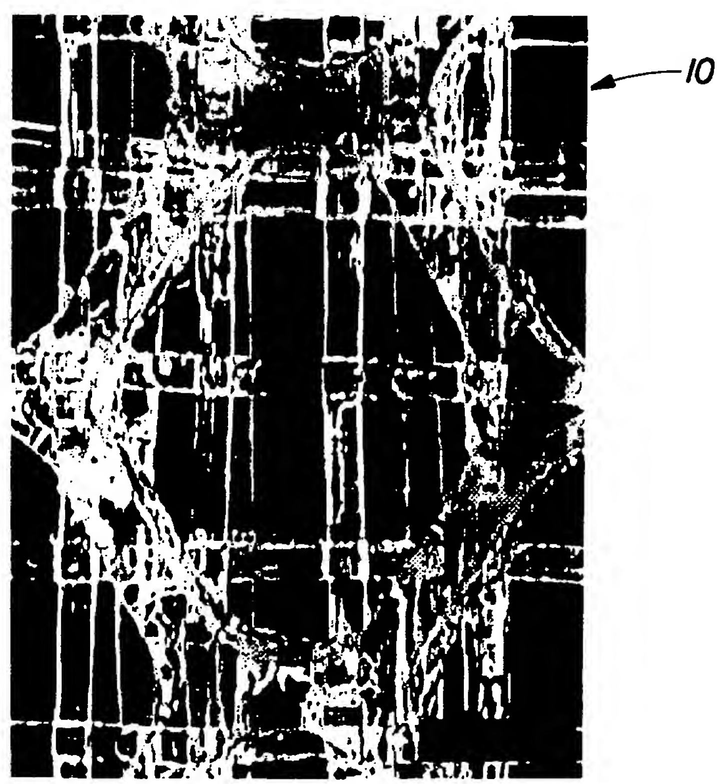

Fig. 6B

International Application No
PCT/IB 98/01442

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 D21F1/00 D21F11/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 D21F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	DE 24 37 303 A (MARX GMBH J J) 12 February 1976 see claim 6; figures ---	1 2-5,7,9
Y	US 5 566 724 A (TROKHAN PAUL D ET AL) 22 October 1996 cited in the application see abstract; figures see column 5, line 14 - column 6, line 12 see column 8, line 8 - line 23 see column 9, line 26 - line 45 ---	2-5,7,9
A	GB 1 230 654 A (SCAPA-PORRITT LIMITED) 5 May 1971 cited in the application see claims see page 2, line 32 - line 41 -----	1,6,8

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
14 December 1998	21/12/1998

Name and mailing address of the ISA	Authorized officer
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1

INTERNATIONAL SEARCH REPORT

information on patent family members

International Application No

PCT/IB 98/01442

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